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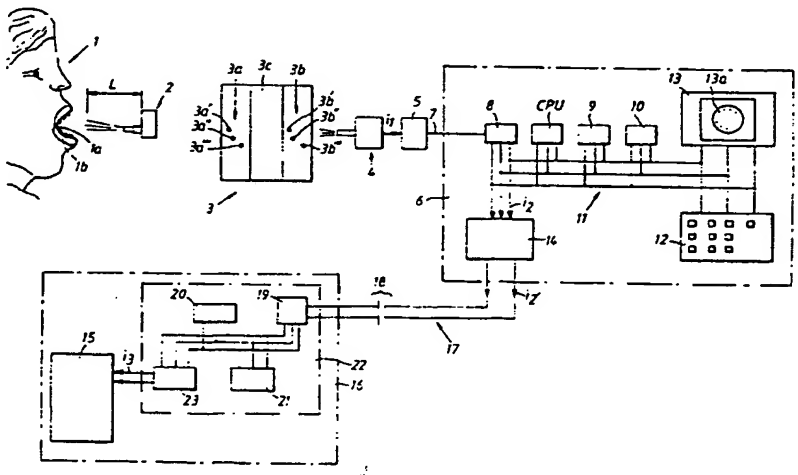

(57) Abstract

For collecting manufacturing data for equipment for production of artificial support members or replacement parts (dental bridges, dental caps, etc.) for the human body, a camera (2) is used for stereophotography. The camera is arranged to take simultaneous pictures (3a, 3b) of the respective body area from different angles at one and the same exposure. Reading equipment scans the said pictures which have been taken and provides digitized data concerning the structure/shape, etc. of the respective area or object/implant. Computer equipment uses the digitized data and can graphically reproduce on its screen, or automatically reproduce, the picture which has been taken. With the aid of identification software, points are identified which are used for calculating the spatial position by means of photogrammetric calculation of spatial coordinates. The manufacturing data is generated as a function of the identifications and calculations which have been made.

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Method and arrangement for collecting data for production of artificial support members or replacement parts for the human body.

TECHNICAL FIELD

The present invention relates to a method for collecting control data or manufacturing data, for example data on cutting coordinates, for one or more machines or manufacturing systems for production of artificial support members or replacement parts for the human body. The said members and parts preferably consist of dental bridges, dental caps or other dental articles for positioning in the mouth cavity. The method utilizes stereophotography in which each imaging is carried out from different angles in relation to the relevant body areas, for example the jaw, teeth, etc., which are to be provided with the said support members or replacement parts. The invention also relates to an arrangement for implementing the said method. The data collected can also be used for or in blasting fungi in the mouth cavity.

PRIOR ART

It is already known to propose arrangements and methods for collecting control data, in which a model is produced and is scanned by reading equipment, and in which the shape of the model can be represented by or with digitized data which is processed or used in computer equipment for production of the manufacturing data.

It is also known to use equipment for stereo-photography of, for example, the mouth cavity of a patient, the photographs being used for determining the positions of the implant and the like in the mouth cavity. The determination of the positions of the implant can in this case be carried out photogrammetrically.

DESCRIPTION OF THE INVENTION

TECHNICAL PROBLEM

The use of models entails relatively complicated and time-consuming procedures for the designing and production of implants and artificial support members for these (dental bridges, dental caps, etc.). The model is produced by, among other things, taking an impression in the patient's mouth, and many patients cannot tolerate, or are averse to, such impression techniques. There is therefore a need for simplified methods and arrangements, for example in the production of dental bridges. The invention aims to solve this problem.

The use of models in itself results in relatively large sources of error in the finished constructions which, on account of inadequate fitting, build static stresses into the patient's mouth and which in the long term cause the collapse of parts of the jaw bone despite the fact that the stresses are relatively small. The invention aims to solve this problem too, and it proposes a method and arrangement which make it possible to eliminate built-in forces of this kind.

The use of stereophotography and photogrammetry for establishing the positions of teeth and implants in the mouth cavity should in itself be able to obviate the use of models which are produced using an impression compound in the patient's mouth. However, equipment used hitherto for stereophotography has proved to be more or less impractical to employ in connection with dental work in the mouth cavity. Stereophotography involves imaging the same jaw area or implant/object from different angles, and this means that it has hitherto been proposed to use several cameras which have been coordinated in terms of their function. The equipment becomes complex, and it is difficult to prevent the movements the patient makes between the exposures from affecting the result. The invention solves this problem too.

Computer equipment for production of dental articles is beginning to be introduced to an ever greater extent on the dental market. It is important to use

computer equipment (personal computers) having easy-to-follow instructions so that the equipment can be used by persons who, when all is said and done, are not computer experts. The invention solves this problem too. This applies also to the proposed camera equipment which, according to the invention, is calibrated for high-quality use in connection with manufacture and has a user-friendly construction. It is important that the camera equipment should be of a conventional type and should not necessitate the use of advanced photography techniques from the point of view of taking pictures. The invention solves this problem too.

Identification of the end surfaces by means of software in the computer equipment must not in itself involve a complicated management of the computer equipment. The invention solves this problem and proposes an embodiment in which standard software sold on the market will be used for the identification.

SOLUTION

The feature which can principally be regarded as characterizing a method according to the invention is, inter alia, that the respective body area in question is stereophotographed using a single camera arranged to take simultaneous pictures of the body area or body areas from different angles at one and the same exposure. The different pictures taken simultaneously in this way are developed and are read by reading equipment which, as a function of the reading, generates digitized data concerning the stereophotographed body area and/or the object or objects which is or are applied in this area and which can in this case consist of an implant or implants. The digitized data is transmitted to computer equipment in which the digitized data is processed or used in order to permit graphic reproduction on the screen of the computer equipment, or on another screen belonging to another medium. Surfaces, for example end surfaces, of the body area in question (a tooth remnant, for example) and/or of the object applied on this area

are then identified, which object, in accordance with the above, can consist of an implant. The identification takes place until the data, collected by means of the computer equipment, concerning the surfaces thus identified is used as control data or manufacturing data. Alternatively, the data can be integrated in the control or manufacturing data together with other function data. This function data can relate, for example, to the available space for the respective support member or replacement part. The function data can also relate to aesthetic requirements placed on the respective support member or replacement part in this context. In one embodiment of the inventive concept, the mucous membrane of the mouth cavity is imaged (photographed) for reproducing the topography of the mucous membrane. The imaging is carried out in conjunction with or prior to the production in question and can, for example, be taken as a basis for the treatment of the patient. The collection of data can also be used in the blasting of fungi in the mouth cavity.

The feature which can principally be regarded as characterizing an arrangement according to the invention is that the camera equipment comprises a single camera which is arranged to be able to take simultaneous pictures of the respective body area or body areas from different angles during one and the same exposure. Also included is reading equipment, which is arranged to be able to scan pictures taken simultaneously with the said camera and to output, as a function of the scanning, digitized data concerning the structure or shape of the said body area or body areas and/or of the object or objects applied in this area or these areas, which objects can, in accordance with the above, consist of implants. The computer equipment employed is arranged to receive and to process or use the said digitized data for graphic reproduction, on the screen of the computer equipment, of the said structure/structures or shape/shapes of the respective area and/or object. The computer equipment is arranged to identify, with the aid

of identification software, the position or positions in space of one or more surfaces, for example end surfaces, of the respective area (tooth remnant, for example) and/or of an object applied on this area, for example the said implant. In addition, members are provided for generating the said manufacturing data with the aid of the data relating to the identified surfaces, if appropriate together with function data on the available space for and/or aesthetic requirements of the respective support member or part, etc.

In one embodiment of the inventive concept, the identification software is arranged to operate with reference markings applied on the said surfaces. These markings preferably consist of circles or have designs of a corresponding geometrical nature. The software performs the identification by, among other things, comparing the simultaneously taken pictures of the respective area(s) and/or objects with the reference markings which are applied or present thereon. Any difference in the comparison can be observed in the geographical reproduction. One or more compensating actions or compensating measures for eliminating the said difference in the graphic reproduction can be carried out on the computer equipment. When a difference in the correspondence between the said pictures and the said reference markings has been eliminated or has been substantially eliminated, the program creates data on the actual position of the surface in question, which position can be represented by the position of the centre point of the surface, of the inclination of the surface in space, etc. A unit which can be applied on the respective area, tooth remnant, implant, etc. is provided with reference markings in the form of circles about the periphery or circumference of the top surface of the unit. The identification program is arranged to identify points in images in the coordinate system of the picture. Data obtained is input for a photogrammetric calculation of image coordinates in accordance with a process which is known per se.

In one embodiment, the said camera is arranged to take pictures in or at the mouth cavity at a distance of 50 to 150 mm. The imaging can involve stereophotography of implants in the jaw, either at the level of the fixture, i.e. down in the jaw in the unhealed state of the latter, or at the level of the spacer, where the jaw is healed and only the spacers on the implant protrude above the healed jaw bone. The centre points and inclinations of the end surfaces can be determined in this way, and the values determined are used for a dental bridge construction, a dental cap construction, or the construction of another dental article. The camera in question can operate with two virtual lens functions arranged at a distance from one another for achieving the stereo effect. The camera can thus effect three images of the respective area or areas and/or object. Two or more images are thus used, which include the images effected with the virtual lens functions. For determining the inclination of the surface, use is made of a surface normal in the form of a three-dimensional vector with a length which essentially corresponds to the length of the radius of the end surface (or equivalent).

The imaging can involve stereophotography of a number of implants, for example 2 to 6 implants. Each implant has in this case essentially the shape of a cylinder, the end surface of which is intended to be identified in space. Adaptations by building the respective implant up to a common level in a dental bridge can be carried out by means of calculations in the computer equipment. The precision of the determination of the solid angle for the implant or the abutment surface of the cylinder, which abutment surface is formed by the said end surface, is of the order of magnitude of 0.01 radians, which corresponds to an error of the order of magnitude of 0.03 mm at the periphery of the implant/cylinder. The precision of the determination of an individual point on the respective area and/or the implant/cylinder, for example centre points in the end surface, is of the order of magnitude of 0.02 mm.

DESCRIPTION OF THE FIGURES

A presently proposed embodiment of a method and arrangement according to the invention will be described hereinbelow with reference to the attached drawings, in which:

Figure 1 shows in outline, and in block diagram form, the chain involved in the production of a dental article for the human body,

Figure 2 shows, in basic diagram form, a radiation pattern for a camera which is used with mirror surfaces for achieving virtual lens functions with which stereophotography can be performed,

Figure 3 shows, from above, end surfaces which have been taken by stereophotography with the camera according to Figure 2, and have been reproduced graphically on a computer screen,

Figure 4 shows, seen in a perspective view obliquely from above, the inclination of an implant and its end surface,

Figure 5 shows, from above, the end surfaces of a number of implants which have been taken by stereophotography and have been reproduced graphically on a computer screen,

Figure 6 shows, from the side, a unit which has been placed on an implant and which is provided with circular reference markings on its top surface, about its periphery, and

Figure 7 shows, in a top view, the unit according to Figure 6.

DESCRIPTION OF A DETAILED EMBODIMENT

A patient is indicated by 1 in Figure 1. Stereophotography with a camera 2 is performed directly on the patient, in his or her mouth cavity 1a. The photography can involve photography of implants which have been implanted into the jaw bone 1b of the patient. The camera is of such a type that stereophotography can take place with a single exposure in accordance with what is described below. The camera is of the miniature camera

type and is described in more detail in the Swedish patent application [lacuna] filed on the same day. The picture is taken at a distance L of the order of magnitude of 50 to 150 mm. Reference number 3 shows a photograph which has been taken with the camera 2. The photograph presents two images 3a, 3b of the same object, but taken from different angles. A third image, which can be present in the zone 3c, is not used in the present case. The photograph as such can be divided into several zones, each one of which presents its own image of the object in question, which object can consist of a jaw bone part, one or more implants, etc. In the present case, the spatial position of an implant is to be identified. In this case, use is made of the end surface of the implant, and of reference markings applied on this end surface, with three reference markings on such a surface having been shown on each image in the respective zone by 3a', 3a'', 3a''' and 3b', 3b'', 3b''' respectively. The images on the photograph 3 are scanned with a reading device 4 which is of a type known per se. The reading device can thus consist of the KODAK photo CD system, Hasselblad's slide scanner, etc. The reading device is in this case arranged to represent, with digital signals i_1, the shape in question which has been read, in the present case attributable to, among other things, the said reference markings. The digitized data is stored in a storage unit 5 and can be transmitted to computer equipment 6. The transmission can be by wire 7, via diskette, without wires, etc. The data i_1 in question is received in the computer equipment in an adaptor unit 8. The computer equipment comprises a microprocessor (CPU), memory elements 9, 10, a bus connection 11 through which all the units of the computer equipment are connected to each other, a terminal 12 and a computer screen 13. Also included is a readout unit 14. The data i_1 is received and processed or used in the computer equipment 6 so as to be able to reproduce graphically, on the screen 13, the body area, the object 13a, etc. which has been photographed and which is imaged on the

photograph 3. The computer operates with a graphics program which is known per se. The computer similarly operates with an identification program, which is known per se, for identifying the shape, spatial position, etc. of the area or the object which has been imaged. An example which may be mentioned of a graphics program is "NIH image" from the National Institute of Health, USA. As an example of an identification program, the last-mentioned program can be used, or "Photo 3D" from Harry W. Townes, Montana, USA. Computation software which can be used is "CAP, K^2-konsultanse", Germany. The computer equipment is operated via the terminal 12 in a manner known per se.

Following identification of shape, position, etc., the identification data i_2 in question is read out to the readout element 14, which in turn transmits control data or manufacturing data i_2' to one or more manufacturing machines 15, or to one or more manufacturing systems 16 which include the said machine/machines. The transmission is effected by wire 17, without wires, via diskette, etc. In the case of wire/wireless transmission, the transmission can be effected via the public telephone network 18. The manufacturing system can include an adaptor unit 19, computer element 20 (CPU), memory and terminal element 21, which can also include a screen in the same way as the computer equipment 6. In Figure 1, the second computer equipment is indicated by 22. In this case too there is a readout unit 23, from which cutting coordinate data and other manufacturing data i_3 are transmitted to the said machine or machines.

Figure 2 shows parts of the function of the camera. The camera has an actual or real lens 24. The imaging surface is indicated by 25, and the camera is provided with two parallel mirror surfaces or reflection surfaces 26, 27. The said mirror surfaces or reflection surfaces are arranged in such a way that two virtual lens functions 28, 29 are created. The said virtual lens functions are situated at a distance L' from one another,

and three images or image zones (cf. 3a, 3b and 3c in Figure 1) are obtained on the imaging surface 25. Each of the two virtual lens functions 28, 29 gives its own image zone and its own image, while the real lens 24 gives an image or image zone pertaining to itself. Imaging of one and the same body area/body areas or object (implant, cap, dental bridge, etc.) is thus obtained through the distance L'.

With the arrangement according to Figure 2, it is possible, by using more mirrors, to obtain more than two image zones, for example four image zones, and consequently four different images. The images are compared in the computer equipment 6 with the aid of the said identification program. According to Figure 3, four different images are compared. A mean value 30 defines a number of centre points 31, 32, 33, 34 and 35 for possible circles through 3 of peripheral points, of which two have been shown by 36 and 37.

In a similar way, the angle of inclination for the body in question can be worked out by calculating the solid angle. Figure 4 shows an end surface 38 of an object 39. A three-dimensional vector is shown by 40, and a radius by 41. Different axes of inclination which are used in the calculation are shown by 42, 43 and 44. A centre point is indicated by 45.

Figure 5 shows the images of five different implants 46, 47, 48, 49 and 50. The centre points and angles of inclination of these implants are estimated in accordance with the above. By means of the fact that the inclinations and the positions of the centre points have been determined in this way, control data (cf. i_2' in Figure 1) can be extracted. The precision of the determination of the centre points and of the angles of inclination is in this case extremely high, and reference is made to the precisions mentioned above.

Figure 6 shows a unit 51. The unit can be fixed on an implant 52 or other object. The unit is provided on its top surface 53 with peripheral, circular reference markings. The positioning and the shape of these

reference markings are shown in Figure 7. The identification program used in the computer 6 can in this case be made to operate with the aid of the said circular reference markings. In accordance with the above, image coordinate data is collected and is used in the calculation of the spatial coordinates, which calculation can be done in a known manner using the photogrammetric computation program.

The invention is not limited to the embodiment shown hereinabove by way of example, but instead can be modified within the scope of the attached patent claims and the inventive concept.

PATENT CLAIMS

1. Method for collecting control data (i_2), for example data on cutting coordinates, for one or more machines or manufacturing systems (16) for production of artificial support members (39) or replacement parts for the human body, the said members and parts preferably being in the form of dental bridges, dental caps, etc. for positioning in the mouth cavity (1a), and utilizing stereophotography in which each imaging is carried out from different angles in relation to the relevant body areas, for example the jaw, teeth, etc., which are to be provided with the said members or parts, characterized in that the respective body area in question is imaged using an imaging device (2) arranged to take simultaneous pictures of the body area or body areas from different angles at one and the same exposure, in that the different pictures (3a, 3b) taken simultaneously with a single imaging device are developed and are read (scanned) by the reading equipment (4) which, as a function of the reading, generates digitized data concerning the imaged body area and/or the object or objects which is or are applied in this area, for example an implant, in that the digitized data is transmitted to computer equipment (6) in which the digitized data (i_1) is processed or used in order to permit automatic reproduction or graphic reproduction (13a) on the screen of the computer equipment (or on another screen), in that surfaces, for example end surfaces (38), of the body area in question (a tooth remnant, for example) and/or of the object/implant (39) applied on this area are identified, and their spatial positions are calculated with a photogrammetric computation program in the computer equipment, and in that the data (i_2) collected and the surfaces thus identified are used as the said control data (i_2') or are integrated in the latter together with function data relating to the available space for and/or the aesthetic requirements placed on the respective support member or replacement part, etc.

2. Arrangement for implementing the method according to Patent Claim 1 for collecting manufacturing data (i_2') for one or more machines or manufacturing systems (16) which can be used for the production of artificial support members (39) or replacement parts for the human body (1), such as dental bridges, dental caps, etc., preferably for use in the mouth cavity (1a), the arrangement comprising reproduction equipment for imaging, for example stereophotography, by means of which pictures (3a', 3a'', 3a''') can be taken from different angles in relation to the body area or areas in question, for example the jaw (1b), teeth, etc. which are to be provided with the said members or parts, characterized in that the equipment consists of a reproduction device (2) which is arranged to take simultaneous pictures (3a, 3b, 3c) of the respective body area or body areas from different angles during one and the same exposure, in that reading equipment (4) is arranged to scan pictures taken simultaneously with the said reproduction device and to output, as a function of the scanning, digitized data (i_1) concerning the structure/shape of the said body area or body areas and/or of the object or objects arranged in this area or these areas, for example an implant, in that computer equipment (6) is arranged to receive and to process or use the said digitized data and to reproduce graphically (13a) on its screen (13), or reproduce automatically, the said structure/structures or shape/shapes of the respective area and/or object, in that the computer equipment (6) is arranged to identify, with the aid of identification software, one or more surfaces, for example end surfaces, or details thereof, of the respective area (tooth remnant, for example) and/or of an object applied on this area, for example the said implant, to spatial position(s), and in that members (6, 14) are arranged for generating or instigating the said manufacturing data (i_2', i_3') with the aid of the data relating to the identified surfaces, if appropriate together with function data on the available space for and/or aesthetic requirements of the respective support

member or part, etc.

3. Arrangement according to Patent Claim 2, characterized in that the identification software is arranged to operate with reference markings (36, 37, 54) applied on the said surface (38, for example), these markings preferably being in the form of circles or corresponding geometrical figures, in that the identification program performs the identification by comparing the simultaneously taken pictures of the respective area(s) and/or objects (39, for example) and the reference markings which are applied or present thereon.

4. Arrangement according to Patent Claim 2 or 3, characterized in that the reproduction device comprises a camera which is arranged to take pictures in or at the mouth cavity (1a) at a distance (L) of 50 to 150 mm, and in that the imaging can involve stereophotography of implants in the jaw (1b), either at the level of the fixture, down in the jaw in the unhealed state, or at the level of the spacer, in the healed state, and with only the spacers protruding above the healed jaw bone, it being possible for the centre points and inclinations of the end surfaces to be determined, and in that the value (i_2') determined can be used for production of a dental bridge construction, a dental cap construction, or another dental construction.

5. Arrangement according to any one of Patent Claims 2 to 4, characterized in that the camera (2) operates with two or more virtual lens functions (28, 29) arranged at a distance (L') from one another for achieving the stereo effect, and in that images of the respective area or areas and/or object which have been effected in this way by the camera [lacuna] a reduced number of pictures with the actual lens functions (28, 29) are included in determining the position of the surfaces, for example by determining centre points in, and inclinations of, end surfaces.

6. Arrangement according to any one of Patent Claims 2 to 5, characterized in that each surface normal (40) is

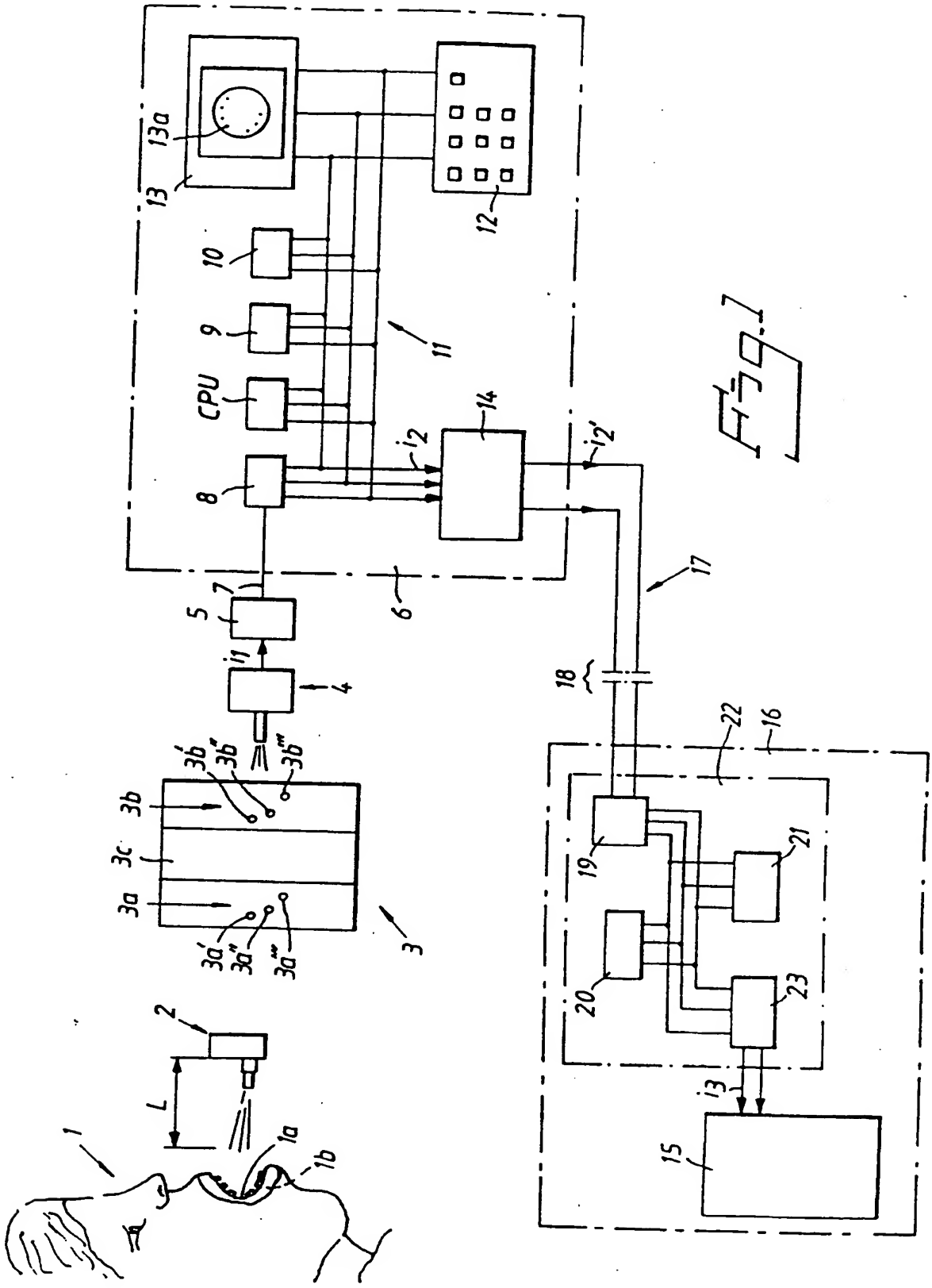
defined as a three-dimensional vector with a length which essentially corresponds to the length of the radius (41) of the end surface (or equivalent).

7. Arrangement according to any one of Patent Claims 2 to 6, characterized in that the imaging involves stereophotography of a number of implants, for example 2 to 6 implants (46 - 50), which have essentially the shapes of cylinders, the end surfaces of which are intended to be identified in space, and in that adaptation by building the respective implant up to a common level in a dental bridge or equivalent can be carried out by means of calculations in the computer equipment.

8. Arrangement according to any one of Patent Claims 2 to 7, characterized in that the precision of the determination of the solid angle for the abutment surface (38) of the implant/of the cylinder, which abutment surface is formed by the said end surface, is of the order of magnitude of 0.01 radians, which corresponds to an error of the order of magnitude of 0.03 mm at the periphery of the implant/cylinder, and/or in that the precision of the determination of an individual point on the area(s) and/or the implant/cylinder, for example centre points in an end surface, is of the order of magnitude of 0.02 mm.

9. Arrangement according to any one of Patent Claims 2 to 8, characterized in that, in a series of peripheral reference markings on the periphery or circumference of an end surface, only three need be determined for indicating the centre point of the end surface.

10. Arrangement according to any one of Patent Claims 2 to 9, characterized in that the mucous membrane in the mouth cavity is imaged in order to reproduce the topography of the mucous membrane, it being possible for the imaging to be effected in conjunction with or prior to the production in question.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i1
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3b'
3b''
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3c
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3a'
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Fig. 1

Fig. 2

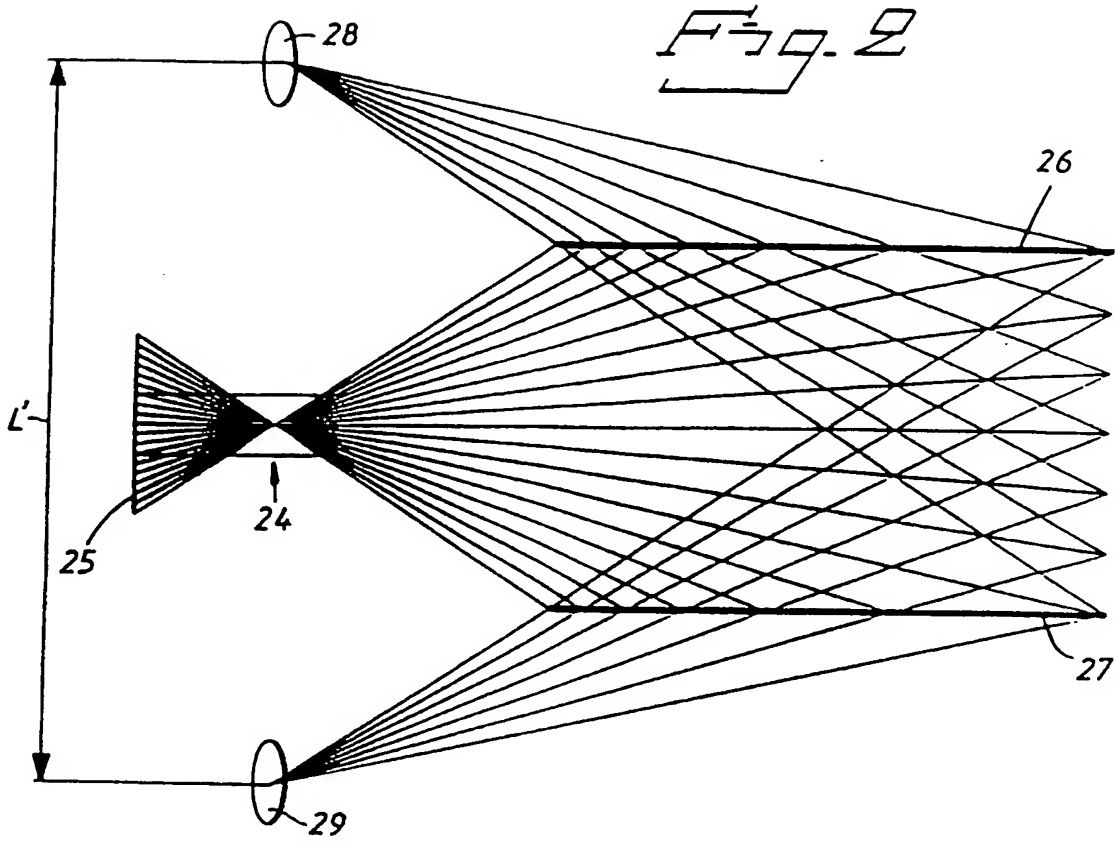


Fig. 3

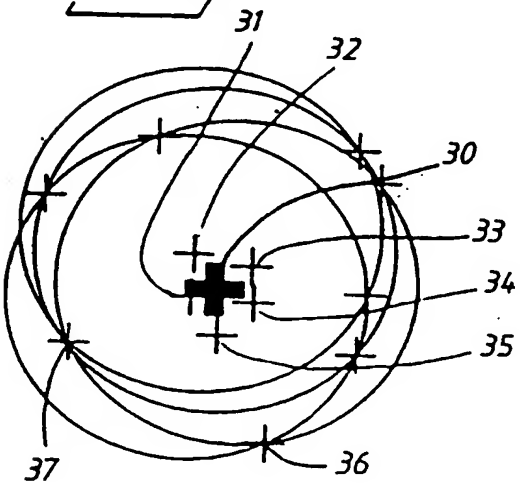


Fig. 4

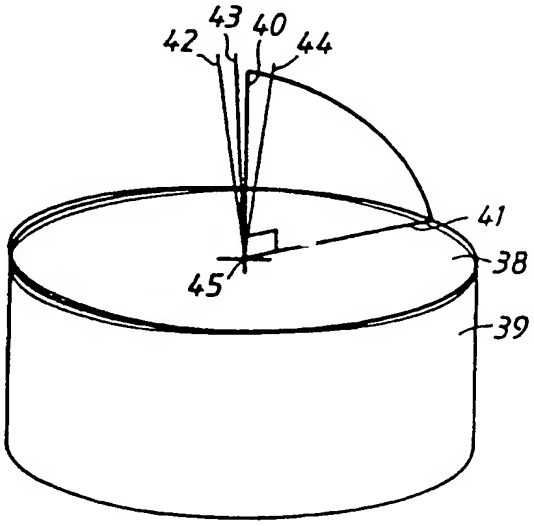


Fig. 5

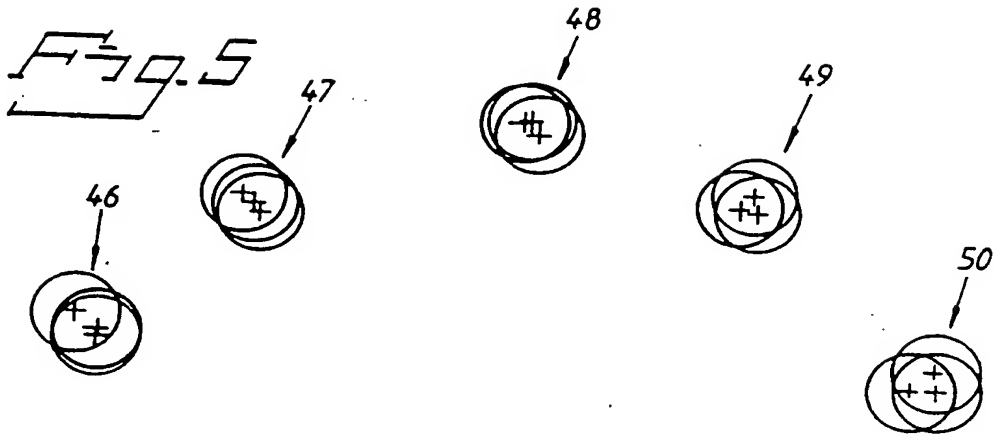


Fig. 6

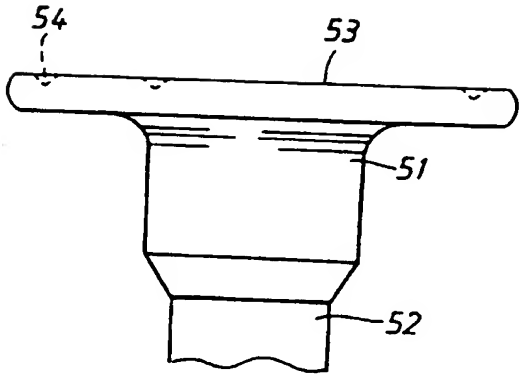
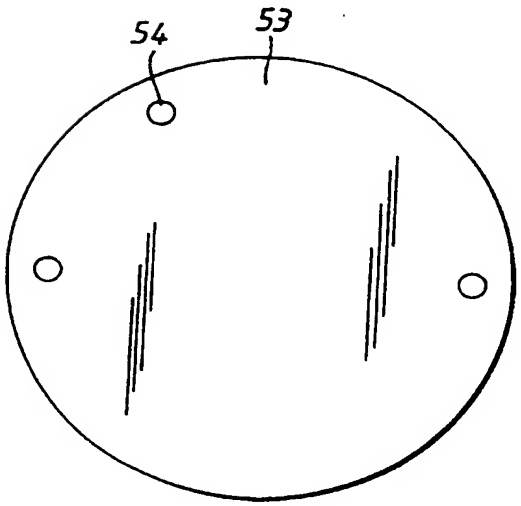


Fig. 7



INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 94/01142

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: A61C 13/00, A61C 19/04
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: A61C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO, A1, 14803 (LINDQVIST, BERIT), 13 December 1990 (13.12.90) --	1-10
A	WO, A1, 9102496 (BERGMAN, MAUD), 7 March 1991 (07.03.91) --	1-10
A	EP, A2, 0490848 (NOBELPHARMA AB), 17 June 1992 (17.06.92) --	1-10
A	EP, A1, 0541500 (NOBELPHARMA AB), 12 May 1993 (12.05.93) --	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 March 1995	17 -03- 1995
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Jack Hedlund Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

09/02/95

International application No.
PCT/SE 94/01142

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO-A1- 14803	13/12/90	NONE		
WO-A1- 9102496	07/03/91	AU-A-	6153190	03/04/91
		CA-A-	2064790	18/02/91
		EP-A-	0591135	13/04/94
		JP-T-	4507358	24/12/92
		SE-B,C-	465498	23/09/91
		SE-A-	8902765	18/02/91
		US-A-	5320462	14/06/94
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		SE-B,C-	468198	23/11/92
		SE-A-	9003967	13/06/92
EP-A1- 0541500	12/05/93	CA-A-	2081588	02/05/93
		JP-A-	5212063	24/08/93
		SE-B,C-	469158	24/05/93
		SE-A-	9103204	02/05/93